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# Metallicity vs. Be phenomenon relation in the solar neighborhood

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**Abstract.** Fast rotation seems to be the mayor factor to trigger the Be phenomenon. Surface fast rotation can be favored by initial formation conditions, such as abundance of metals. We have observed 118 Be stars up to the apparent magnitudes $V = 9$ mag. Models of fast rotating atmospheres and evolutionary tracks were used to interpret the stellar spectra and to determine the stellar fundamental parameters. Since the studied stars are formed in regions that are separated enough to imply some non negligible gradient of galactic metallicity, we study the effects of possible incidence of this gradient on the nature as rotators of the studied stars.

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## 1. Aim

In the present paper we would like to know whether the content of metals in the formation regions of stars can introduce some signature in the $(\tau/\tau_{\rm MS}, M/M_\odot)$ diagram [$\tau/\tau_{\rm MS}=$ fractional age the stars can spent in the main sequence (MS) evolutionary phase]. In fact, it was shown by Stepień (2002) that magnetic fields not exceeding 400 G can spin up early type stars in the PMS life, while stronger magnetic fields spin them down. However, since the mechanism acts through magnetic mass-accretion and magnetic-disc locking, the efficacy of the magnetic interaction can differ according to the metallic content in the star and its gaseous environment.

It has been shown that Be stars rotate at $\Omega/\Omega_c \sim 0.9$ (Frémat et al. 2005). This rotational rate can be attained in the MS evolutionary phase only if stars have high rotational rates early in the ZAMS. It is expected then that the presence of magnetic fields and its effectiveness at establishing high initial stellar surface rotations can be different according to the metallic content of the medium where they are formed: *age vs. mass* distributions may then be somewhat different. Our aim is to study Be stars situated towards the *galactic-center* and in the *anti-center* directions and see whether some information can be drawn form the *age vs. mass* distributions.

## 2. Method

High resolution and S/N spectroscopic observations were carried out on 118 Be stars in the Southern Hemisphere with FEROS spectrograph at ESO/La Silla

(Chile) and with the Coudé spectrograph at the 1.60m telescope of MCT/LNA (Brazil). ESO spectra were taken with a spectral coverage of 3560-9200 Å and typical S/N $\sim$ 200. LNA spectra were obtained with a WI098 CCD from 3939 Å to 5060 Å with a reciprocal dispersion of 0.24 Å/pixel.

The stellar fundamental parameters were obtained in two steps. First, we derive the ($T_{\rm eff}, \log g$) parameters with classical non-LTE model atmospheres that we call *apparent*. In the second step, we correct the *apparent* parameters for rotational effects due to stellar deformation and the concomitant gravitational darkening effect. We obtain thus the *parent non rotating counterpart* fundamental parameters, i.e. those which depict homologous stars without rotation (Frémat et al. 2005). We correct them once more to obtain the fundamental parameters *averaged* over the entire deformed stellar surface, which are finally used to interpolate masses $M$ and ages $\tau$ of the studied stars in evolutionary tracks calculated for rotating objects (Meynet & Maeder 2000, Zorec et al. 2005).

A first estimate of the effective temperature and gravity is attempted through the fit of equivalent widths of many spectral lines, including Balmer lines and line intensity ratios such as He II/He I and Si III/Si II. Once the first guess of ($T_{\rm eff}$, $\log g$) is established we perform a detailed fit of the observed lines with non-LTE spectra synthesized with TLUSTY (Hubeny 1988) and SYNSPEC (Hubeny, Hummer, & Lanz 1994) codes. Ratios of two neighboring ionization states elude sensitivities to abnormal element abundances carried by the fast rotation. However, the occurrence of He II lines in the visible is constrained to stars hotter than B2 ($T_{\rm eff} > 22000$ K). As most B and Be stars in our sample show only He I lines, we studied many combinations of He I line ratios and used those with the less dependence on the helium abundance. Fixing $\log g$ values, we calculated synthetic He I and He II line profiles for different temperatures from 15000 to 30000 K and helium number abundances He/H ratios from 0.001 to 0.3. The analysis performed with neutral helium lines (He I$\lambda\lambda$ 4009, 4026, 4121, 4144, 4388, 4438, 4471 and 4922) show that only a few combinations of them (He I4922/He I4026, He I4438/He I4144, He I4438/He I4026, He I4438/He I4009, He I4144/He I4121) are less sensitive to the helium content. The *apparent* projected rotational velocity $V \sin i$ was derived from the first zero of the Fourier transform of the He I$\lambda$4471 Å line profile. The *apparent* $V \sin i$, $T_{\rm eff}$ and $\log g$ were then corrected for rotational effects (Frémat et al. 2005, Zorec et al. 2005).

## 3. Results and conclusions

The evolutionary tracks used to calculate masses and ages are for rotating stars (Meynet & Maeder 2000, Zorec et al. 2005). The distribution of fractional ages ($\tau/\tau_{\rm MS}$ = age/time spent in the MS) against the stellar mass of all studied Be stars is shown in Fig. 1a. In this figure we see that *all studied stars, but one, lay below the TAMS.* Although most of the studied stars lay in the second half of the MS strip, a non negligible number of them is still in the first half of the MS evolutionary phase. Quite similarly to what was found in Zorec et al. (2005) *a lack of stars with masses $M \lesssim 7M_{\odot}$ below $\tau/\tau_{\rm MS}$ = 0.5 is noticeable.* In our sample, stars with masses $M \gtrsim 12M_{\odot}$ approach the TAMS. This may be due to their fast evolution and perhaps to some lack in our stellar sample of massive

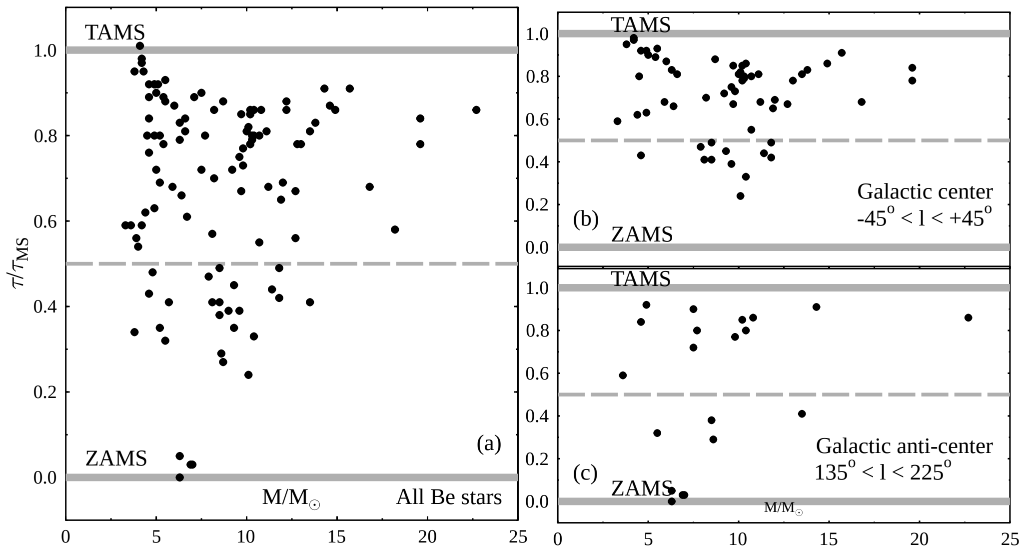


Figure 1. (a) Fractional ages $\tau/\tau_{MS}$ ($\tau_{MS}$ = time spent in the MS) against the mass of all studied Be stars.(b) Same as (a) for Be stars located towards the galactic center. (c) Similar to (a) for Be stars located towards the galactic anti-center

Be stars with ages $\tau/\tau_{\rm MS} \lesssim 0.5$. This lack can also be produced by a loss of angular due to their high mass-loss rates. They can become low rotators rapidly and thus be impeded to display the Be phenomenon any more.

In order to separate the stars in two sets carrying possible information on differences in initial matallicity content, we separated them into "galactic-center" and "galactic anti-center" groups. Fig. 1b shows that there is no noticeable difference in the *"age vs. mass"* distributions thus obtained. The most striking differences are: a) the number of Be stars in the "galactic-center" group outnumbers the "anti-center" one; b) there are younger Be stars in the anti-center direction. Finding a) may agree with the fact that low metallicity favors fast rotation (Maeder et al. 1999). However, the distinction between both groups could be more reliable if we could see differences in the number fractions N(Be)/N(B+Be).

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